# MALAYSIAN ASTRONOMY OLYMPIAD 2019

## Reading Material

Important mathematical concepts and skills: -

1. Algebra
2. Trigonometry & circle
3. Vector analysis
4. Derivation and integration
5. Indices and logarithm
6. Conic sections

Important basic understanding of physics required:-

1. Classical mechanics
2. Wave and optics
3. Thermodynamics

These concepts and skills will be applied a lot in understanding astronomy and astrophysics and answering the questions.

## POSITION AND TIME

**Angular distance:** Measures of apparent distance between two point in the sky as observed by an observer in unit degree.

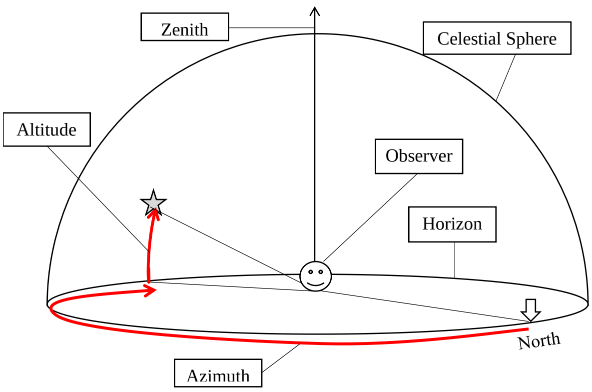
**Horizon:** The line at which the Earth's surface and the sky appear to meet.

**Azimuth:** measures of angular distance in degree, from 0 to 360 starting from the north, eastward along the horizon.

**Altitude:** Measures of angular height of a point in the sky, from the closest point on the horizon.

**Horizontal coordinate system:** coordinate system that applies the altitude-azimuth coordinates

**Equatorial coordinate system:** Coordinate system that consists of the R.A and Dec coordinates.

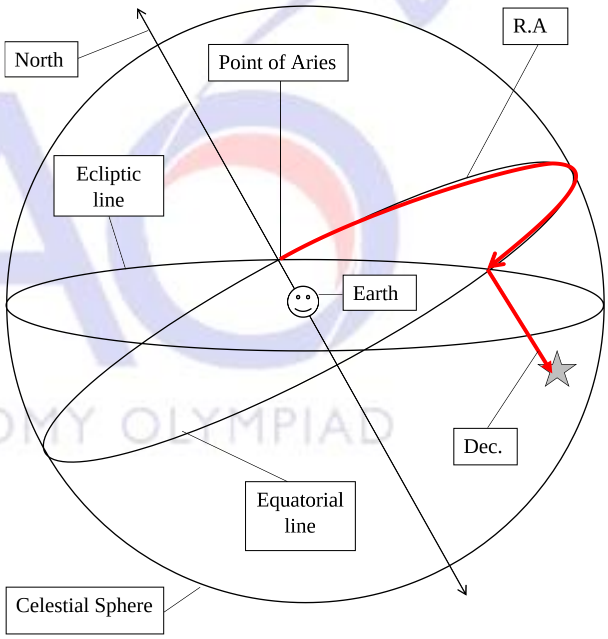



**Point of Aries:** the point where the equatorial line crosses the ecliptic line where the ecliptic line moves from the southern hemisphere to the northern hemisphere of the sky.

**Equatorial Line:** line that divides the sky into northern and southern hemispheres. It is positioned along the equi-distance position from the north celestial pole and the south celestial pole.

**Right-ascension (R.A.):** Measures of distance from 0 Hour to 24 Hour from the Point of Aries, eastward along the equatorial line.

**Declination (Dec.):** Measures of angular distance from 0o to 90o from the equatorial line to the point in the sky. (-) symbol denotes the objects that are in the southern hemisphere.




**Parallax:** The apparent motion of a relatively close object to a more distant background as the location of the observer's location.

$$distance = baseline \times \frac{57.3°}{parallax}$$

**Law of sines and cosines** (+ cyclic change)

$$\frac{a}{\sin\alpha} = \frac{b}{\sin\beta} = \frac{c}{\sin\gamma}$$

$$c^2 = a^2 + b^2 - 2ab\cos\gamma$$

**Spherical law of sines and cosines** (+cyclic change)

$$\frac{\sin a}{\sin \alpha} = \frac{\sin b}{\sin \beta} = \frac{\sin c}{\sin \gamma}$$

$$\cos c = \cos a \cos b + \sin a \sin b \cos \gamma$$

**Paralaksinis trikampis:** spherical triangle, consists of zenith Z, celestial pole P + given star S, ZP = 90 – $\phi$ ($\phi$- latitude), PS = 90 $-\delta$ ($\delta$ - declination), ZS = z (z- zenith distance), angle ZPS is hour angle $t$ (measured from south clockwise), angle SZP is 180 – A (A- azimuth, measured from south clockwise); it provides transformation between azimuthal (A,z) and equatorial coordinate system (t,δ) resp. ($\alpha$,$\delta$) where α = $\vartheta$ – $t$ ($\vartheta$- sidereal time, α measured from vernal equinox point counter-clockwise) - just use spherical law of sines and cosines. The equation of time = $t_{app} - t_m$ ($t_{app}$ - apparent solar time, $t_m$- mean solar time).

**Precession**: period approx. 26000 y, vernal equinox point moves in the opposite direction than right ascension increases.

**Aberration**: tg $\alpha \approx \alpha = v_{\perp}/c$, $v_{\perp}$ is the component of velocity perpendicular to coming rays.
Refraction: near horizon approximately 35.4′

**Astronomical Unit, AU:** Earth-Sun distance= 149 million Km.

**Parsec, Pc**: the distance at which the parallax is exactly 1 arc-second, 206,000 AU.

**Universal time, UT:** the standard time in the time zone of 0° longitude.

**Epoch. 2000**: the measurement of star's position with date and time relative to which a computer's clock and timestamp values are determined. epoch 2000.0 begins at 1200 UTC on January 1, 2000.

**Julian Date**: the number of elapsed days since the beginning of a cycle of 7,980 years invented by Joseph Scaliger in 1583. The starting point for the first Julian cycle began on January 1, 4713 B.C.

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## <u>STAR'S LIGHT AND SPECTRUM</u>

**Magnitude**: logarithmic scale of the brightness of the star

**Apparent Magnitude:** the magnitude of the star as seen by the observer

**Absolute Magnitude**: the magnitude of the star as observed from 10pc away

**Luminosity, *l***: The total amount of energy that a star puts out as light per second.

**Flux, *ρ*:** brightness, energy of the star emitted per unit area.

$$\rho \propto l \cdot R^2$$

Where *R* is distance.

**Intensity Ratio**

$$\frac{I_A}{I_B} = 2.512^{(M_B - M_A)}$$

Where *I*=star's intensity; *M*=star's absolute magnitude.

**Luminosity of a star**

$$L \propto R \cdot T$$

Where *L*= luminosity; *R*= radius; *T*= surface temperature.

**Pogson's Equation**

$$m_1 - m_2 = 5 \ \log \frac{I_1}{I_2}$$

$$m - M = 5 \ \log R - 5$$

Where *m*=apparent magnitude; *M*= absolute magnitude; *R*=distance from observer

**Wien's Law**

$$\lambda_{max} = \frac{2.9}{T}$$

Where $\lambda_{max}$= the peak wavelength of the emitted light from a black body; *T*= star's temperature.

**Stefan's law**

$$\rho = \sigma T^4$$

**Stefan-Boltzman Law**

$$l = 4\pi r^2 \sigma T^4$$

Where $\sigma$=5.67×$10^{-8}$W/$m^2$·$K^4$

**Spectral classification**: (**W**- Wolf-Rayet stars) **O**h **B**e **A** **F**ine **G**irl and **K**iss **M**e **L**ike **T**hat! (**Y**- substellar objects)

**Luminosity classes**: **0 -** hypergiants, **I -** supergiants, **II** -bright giants, **III -** normal giants, **IV -** subgiants,

**V** - mainsequence stars, **VI** - subdwarfs, **VII** - white dwarfs (Sun is G2Vstar).

**Chandrasekhar limit:** (between white dwarf and neutronstar) 1.4 $M_{\odot}$,

**TOV limit:** (between neutron star and black hole) 1.5–3 $M_{\odot}$

**Doppler effect:** motion-induced change in the observed wavelength (or frequency).

$$\frac{\lambda_{apparent}}{\lambda_{true}} = \frac{f_{apparent}}{f_{true}} = 1 + \frac{v_{recession}}{v_{light}}$$

Where $\lambda$=wavelength; *f*= frequency; *v* = speed

**Redshift, Z:** longer wavelength as observed of the light emitted from the source that is moving away from the observer.

$$Z = \frac{\Delta\lambda}{\lambda_o}$$

Where $\Delta\lambda$= wavelength shift; original wavelength

**Kirchhoff's Law**

1. A luminous solid or liquid, or a sufficiently dense gas, emits light of all wavelengths and so produces a continuous spectrum;
2. A low- density, hot gas emits light whose spectrum consists of a series of bright emission lines that are characteristic of the chemical composition of the gas;
3. A cool, thin gas absorbs certain wavelengths from a continuous spectrum, leaving dark absorption lines in their place, superimposed on the continuous spectrum.

**Energy-frequency relation**

$$E = hf$$

Where *E*= photon energy; *h*= Planck's constant= $6.63\times10^{-34}$Js; *f*= frequency.

Energy during Electron transitions in the hydrogen atom

$$\Delta E = R\left(\frac{1}{m^2} - \frac{1}{n^2}\right)$$

Where R≈13.6eV, $\Delta E$ is the energy absorbed by transition from *m*-th to *n*-th level (*m*= 1- Lyman, *m* = 2- Balmer, *m*= 3- Paschen)

**Ideal gas**

$$pV = nRT$$

$$U = \frac{fNkT}{2}$$

Where *p* = pressure of gas, *V*= volume of gas, *n*= no. of mol., *T*=temperature of gas

$$v_{RMS} = \sqrt{\frac{3kT}{M}}$$

$$v_{prob} = \sqrt{\frac{2kT}{M}}$$

Where *m* = mass

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## TELESCOPE & INSTRUMENTATION

**Angular resolution**: the ability of a telescope to resolve the smallest angular distance between two objects.

$$\Delta\theta = \frac{1.22\lambda}{D}$$

Where $\Delta\theta$= angular resolution (rad); *D*= telescope's aperture (m)

**F-ratio of a telescope**

$$Focal\ ratio = \frac{f}{d}$$

Where *f*= focal length; *d*=telescope's aperture

**Magnification,*M***

$$M = \frac{f_o}{f_e}$$

Where $f_o$ = focal length of objective lens/mirror; $f_e$ = focal length of eyepiece used.

**Light-gathering power, LGP**

$$LGP \propto d^2$$

Where *d*= telescope's aperture

# GRAVITY & PLANETARY MOTION

## Gravitational acceleration, g

$$g = \frac{Gm_1 m_2}{R^2}$$

Where $G$=gravitational constant= $6.67\times10^{-11}$Nm$^{-2}$kg$^{-2}$; $m$= mass; $R$= distance between the two bodies.

$$E_{pot} = -\frac{Gm_1 m_2}{r}$$

$$E_{tot} = -\frac{Gm_1 m_2}{2a}$$

## Escape velocity, $v_e$

$$v_e = \sqrt{\frac{2GM}{R}}$$

Where $M$=mass of main object

**Orbital velocity,** parabolic orbit and elliptical orbit

$$v_{para} = \sqrt{\frac{GM}{R}}$$

$$v_{ell} = \sqrt{GM\left(\frac{2}{R} - \frac{1}{a}\right)}$$

## Kepler's law of planetary motion

1. Planet orbits around the sun in an elliptical orbit, with the centre of mass located at one of the focus;
2. An imaginary line connecting the Sun to the planet sweeps out equal areas of the ellipse in equal intervals of time.
3. The square of the orbital period of the planet is directly proportional to the cube of the semi-major axis.

   $$\frac{(a_1 + a_2)^3}{P^2} = \frac{G(m_1 + m_2)}{4\pi^2}$$

   Where $P$= orbital period (Earth years); $a$=semi-major axis (A.U); $m$= mass (solar units).

## Schwarschild radius

$$R_s = \frac{2GM}{c^2}$$

Where $c$ = speed of light